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Plasma Flow in a Multipole Magnetic Channel

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PLASMA FLOW IN A MULTIPOLE FIELD

The flow of ionized gas (plasma) and its interaction with magnetic fields are basic areas of plasma research. Control of the state of the plasma, its direction of flow and its purity are among the broad applications of knowledge in these areas. Specifically, this experiment is concerned with measuring the behavior of a plasma as it enters and flows along the "magnetic channel" created by a multipole magnetic field. Measurements will be made to determine changes in the density and energy of the plasma as it moves down the field and to determine local plasma-field interactions, i.e., electric fields, evidence of turbulent flow and loss of particles from the stream.

SUMMARY AND CONCLUSIONS

A conical theta-pinch gun has been built and its performance measured. Tests to date show gun performance to be in general agreement with performance reported in other investigations (Refs. 1 and 2). Plasma velocities of from 3 to 7×10^6 cm/sec were measured for hydrogen (Fig. 3). The multipole field has been designed; fabrication will begin in the near future.

FUTURE PLANS

Measurements of the conical theta-pinch gun performance will be a primary area of effort in the immediate future. This will both add to our understanding of the gun and serve to perfect diagnostics for the experiment. Fabrication and initial testing of the multipole field and power supply will also go forward in this period. Once the gun and multipole field are ready, flow in the field will be studied at several density-particle energy conditions. If necessary, the theta-pinch gun will be used to extend the available range of conditions.

DISCUSSION

The multipole magnetic field is shown in Fig. 1. The four circular conductors carry current in the same direction. Current returns in the outer conducting sheet, contoured to approximate a flux line. The slots in this wall provide means for optical measurement and access for instrumentation. The diagonal distance between conductors will be 4-1/2 inches and peak current per conductor will be 40,000 amperes. Field strength is zero on the axis, about 2 kilogauss in a region about seven-tenths of the way to a conductor and approximately 10 kilogauss in the bridging region in back of the conductors. The bridge width is equivalent to six gyro radii for protons of 100 eV perpendicular energy. Ohkawa and Kerst (Ref. 3) have shown that the multipole field provides hydromagnetically stable confinement of stationary plasma.

A brief, first order, description of plasma behavior in this experiment follows. We begin with the plasma entering the field with an initial axial velocity. Where field and plasma mix, electric field will be established orthogonal to the magnetic field to maintain the axial drift. Gradient B drift fields, or magnetic pressure in the case of a highly diamagnetic plasma, will act to contract the plasma radially and extend it axially. Some plasma will extend along field lines into the bridging region. Particles will be lost from the main plasma stream by contact with the conductor supports in the bridging region and possibly by "stripping" off of particles at the plasma-field boundary. Turbulent flow effects may also appear in some regions of the plasma-field interface. It will be left to the measurements to reveal the more complex features of this plasma-field experiment.

Our present plan for the experiment is to make our first studies on plasma in a region where collisions should play a major role, i.e., density about 10^{15} and particle energy of a few tens of electron volts. Once we have attained a degree of understanding of this regime, plasma gun parameters will be changed to provide higher particle energies. Densities as low as 10^{13} and particle energy up to 200 eV will be studied.

We are still considering the instrumentation requirements for this experiment. The devices and instruments which we are now planning are discussed here. An image converter camera will observe the multipole field region both axially and transversely to provide helpful visualization of the plasma flow. Magnetic probes will measure diamagnetic effects and possibly turbulence. Calorimeters and a small ballistic pendulum will determine the momentum and energy cross section of the flow. An energy analyzer will give time-resolved particle energy data. Electric fields in the boundary region will be measured with electrostatic double probes. We will try to measure particles lost into the static magnetic field from the passing plasma by use of the "plasma eater" device described by Alexeff and Neidigh (Ref. 4).

Figure 2 shows some of the early data obtained with the conical gun. Data are shown for two operating conditions. In both cases the main conical coil was driven in the same manner - 2100 Joule bank storage, 80 kc ring frequency, 26 kilogauss peak field and field strength ratios of 1.25 from muzzle to breech. In these tests the gun is fired into a B_Z field of 2000 gauss. We see here integrated signals from magnetic loops placed at 10 cm intervals along the field. In these records plasma is seen for each of several half-cycles. In the experiment the gun current will be short circuited at the second half-cycle maximum eliminating these successive low energy plasma outputs from the gun and reducing interference with measurements.

The principal difference in the two records derives from the initial gas distribution set up by the fast gas valve which provides hydrogen for the gun. In Case I, we have a higher plenum pressure but a shorter time elapsed from activation of gas valve to firing of the gun. The timing of these events and the distances are such that we believe that in Case I the gun is fired at a lower gas density and with only a small amount of gas ahead of the gun. In Case II, density should be near its peak value and comparable values of gas density should be found many centimeters ahead of the gun.

The records for Case II show clearly the longitudinal spreading and decreasing lateral energy of the plasma as it proceeds down the field. A higher plasma velocity is evident in Case I. Signals from the plasma originating with the second half-cycle of gun current have been emphasized in Fig. 2.

The data from these second half-cycle signals are plotted in Fig. 3. As indicated the slower mode velocity is 3×10^6 cm/sec while the faster mode gives close to 7×10^6 cm/sec. The decrease of transverse energy density with time due to longitudinal extension of the plasma is evident.

REFERENCES

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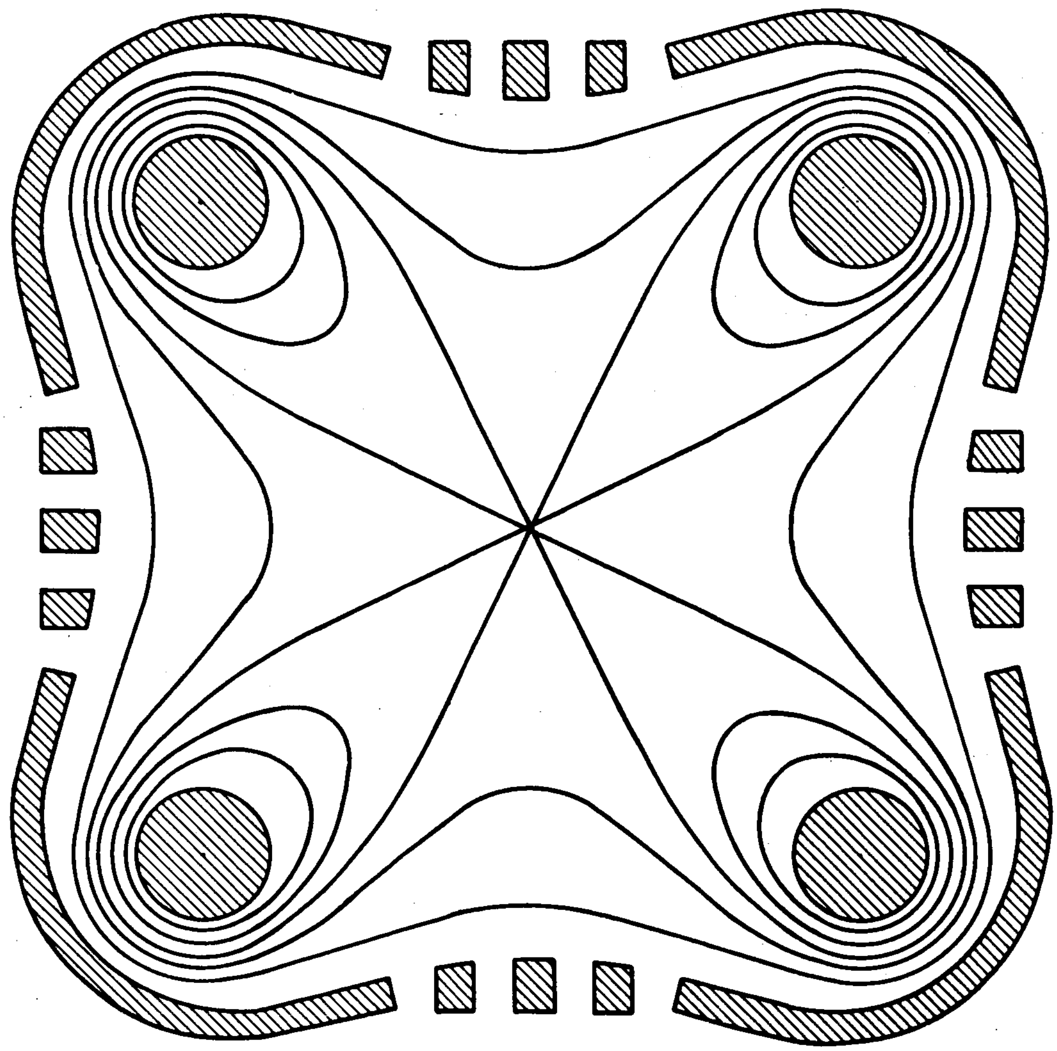
4. I. Alexeff and R. V. Neidigh, Nuclear Fusion, 1963, Vol. 3, p. 23.



MULTIPOLE FIELD CONFIGURATION

FIGURE 1

CONICAL GUN MAGNETIC LOOP DATA

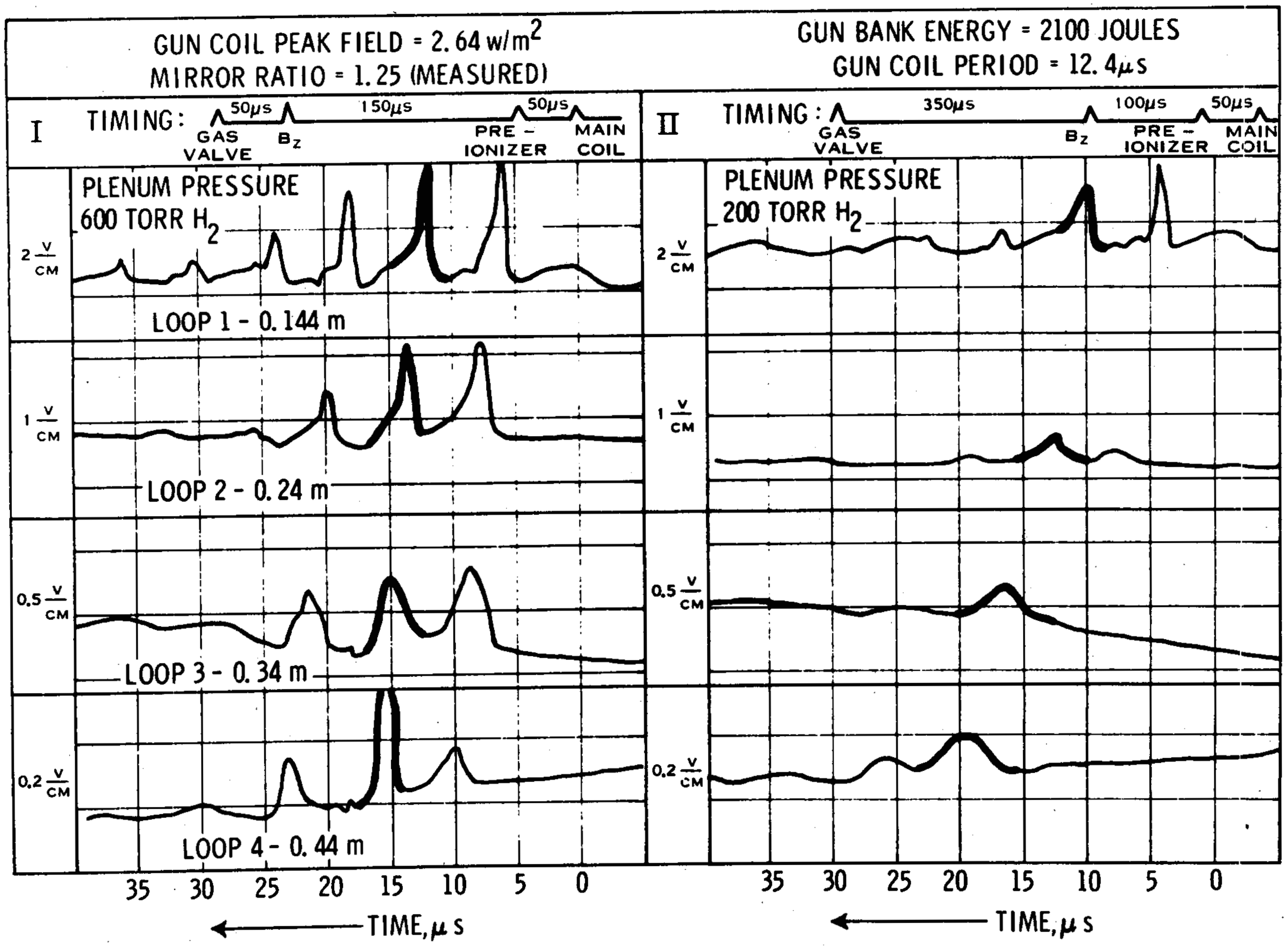


FIGURE 2

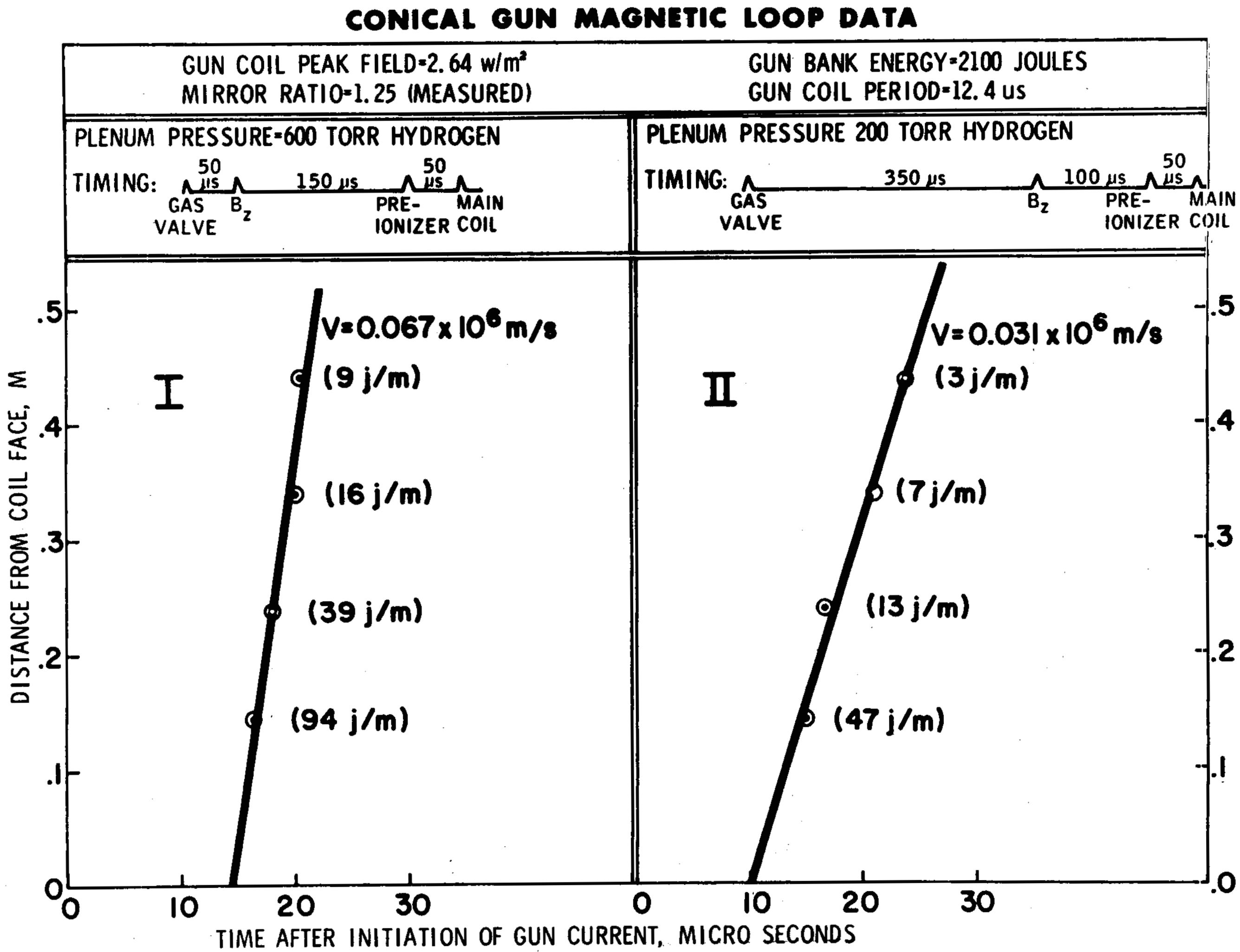

CONICAL GUN MAGNETIC LOOP DATA
GUN COIL PEAK FIELD=2.64 w/m²
MIRROR RATIO=1.25 (MEASURED)
GUN BANK ENERGY=2100 JOULES
GUN COIL PERIOD=12.4 us
PLENUM PRESSURE=600 TORR HYDROGEN
TIMING: GAS VALVE 50 µs Bz 150 µs PRE-IONIZER 50 µs MAIN COIL
PLENUM PRESSURE 200 TORR HYDROGEN
TIMING: GAS VALVE 350 µs Bz 100 µs PRE-IONIZER 50 µs MAIN COIL
I
V=0.067 x 10^6 m/s
(9 j/m)
(16 j/m)
(39 j/m)
(94 j/m)
II
V=0.031 x 10^6 m/s
(3 j/m)
(7 j/m)
(13 j/m)
(47 j/m)
DISTANCE FROM COIL FACE, M
0
.1
.2
.3
.4
.5
0
10
20
30
TIME AFTER INITIATION OF GUN CURRENT, MICRO SECONDS

FIGURE 3